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METHODS OF BREEDING ONIONS[1]

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Breeding studies with the onion were begun at Davis in 1923. At first, the object was to develop a more uniform strain of Australian Brown. As the work progressed, however, the program was gradually expanded. At present, besides the improvement work with this variety, attention is being given to the development of onions that will resist pink root, mildew, and thrips; to the selection of nonbolting strains of Sweet Spanish; and to studies of the way in which the scale and flesh color, foliage color, shape, and other characters are inherited. In all this breeding work, special methods have had to be developed. Those that have proved best at Davis may need modification in other districts. At Davis, climatic conditions are nearly ideal for onion breeding. During May and June, when the plants are in bloom, atmospheric conditions are usually very favorable for pollination: rain seldom falls, the days are generally bright, and there is no dew. The plants, consequently, can be enclosed with very little danger of mildew.

DEVELOPMENT OF THE INFLORESCENCE AND THE FLOWER

Usually the mother bulbs are planted in late November or in December. Toward the end of February, if the plants are dissected, the flower stalks can be distinguished just above the stem plate. Sometime during March, as a rule, they emerge from the surrounding sheaths. They elongate rapidly, the developing buds being protected under the bracts. Finally the bracts are ruptured, and a few days later the first flower of the inflorescence opens.

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When the two outer whorls (perianth) of the flower first expand, (fig. 1) the pistil is still immature; but soon the stamens begin to shed their pollen. There are six stamens in each flower, an inner and an outer whorl each containing a set of three. Those of the inner whorl are first to

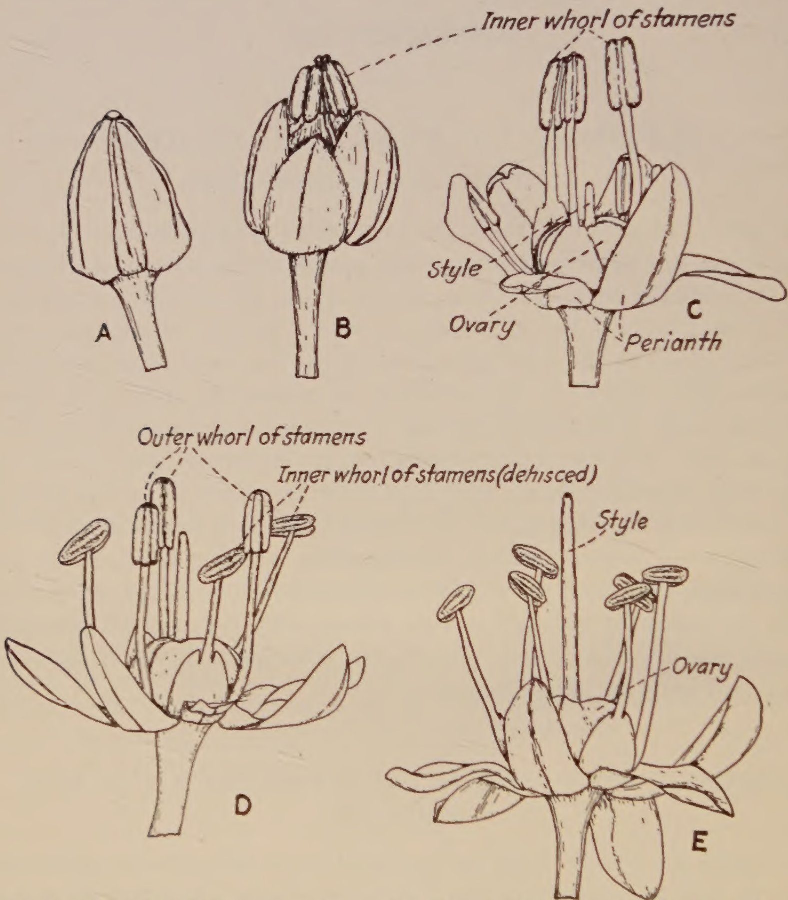

Fig. 1.—Method of flower-opening and pollen-shedding in the onion. *A*, flower bud just before opening. *B*, the two outer whorls of floral organs expanding and the inner whorl of stamens elongating. *C*, just before the shedding of pollen by the inner whorl of stamens; note the short style. *D*, the inner whorl of three stamens has shed its pollen, and the outer whorl of three stamens has elongated. *E*, all six stamens have shed their pollen; note the long style, now receptive. (From *Truck Crop Plants*. McGraw-Hill Book Co., Inc., New York.)

shed their pollen, dehiscing one after the other at irregular intervals. Next, the anthers of stamens in the outer whorl also dehisce at irregular intervals. This is the regular order of dehiscence, though occasionally anthers of the outer whorl discharge their pollen first. All the pollen is

shed before the stigma becomes receptive. When the flower first opens, the style is about 1 mm long. It continues to elongate, but does not reach its maximum length of about 5 mm until some time after all pollen has been shed. The flowers of a single head may continue to open over a period of two weeks or longer.

A detailed study of anther dehiscence was made from June 2 to June 4, in 1923. Fifty flowers on as many different plants were tagged at 4 p.m. on June 2. Each flower had the perianth fully expanded, and the stamens had not dehisced. It was 23 hours before all the anthers of any flower had dehisced, and about 47 hours before shedding of the pollen was completed. Most of the pollen was shed between 9:30 a.m. and 5 p.m.

In the field, cross-pollination probably predominates; but there is some selfing. The chief agencies of pollination are various species of insects, which go from flower to flower, either gathering pollen or visiting the nectaries in the axils of the three inner stamens.

METHOD OF HANDLING PLANTS FOR SELFING

The plants to be selfed are usually set in the field sometime in the fall or early winter. Varieties such as California Early Red and Italian Red, which do not keep well in storage, are generally planted in late September or October. The storage types, such as Australian Brown, are usually set in the field in late November or December. Bulbs are spaced about 12 inches in furrows 3 feet apart (fig. 2) and are then covered with soil to prevent freezing. The plants develop a good root system during the winter, but the scantiness or luxuriance of the foliage depends upon climatic conditions. As a rule, the flower stalks emerge from the surrounding sheaths sometime in March, and the first flowers open in early May. The entire inflorescence is then immediately enclosed within a manila paper bag. Varieties with large flower heads, such as California Early Red and Italian Red, are covered with one-pound paper bags, tied closely so that the flowers within are crowded. This practice seems to give a better set of seed, although the point has not been definitely proved. If the bags are small and are tied close to the inflorescence, very little surface is exposed—a very important consideration where strong winds are prevalent during the pollinating season. Square-bottomed bags are used (fig. 3); and the necessary data, such as pedigree and date of bagging, are written on the bottom. The plots are gone over twice each day, and the heads that have open flowers are bagged. By bagging twice each day, one can get the exact date when

each plant blooms; the main purpose, however, is to prevent insects from visiting open flowers and bringing in foreign pollen. Even though the stigmas are not receptive until several days after the flower first

Fig. 2.—All the bulbs that are to be selfed are staked and labeled at the time of planting. The center row is left vacant for a planting of corn. (Photographed February 20, 1928.)

Fig. 3.—Selfing onions at the University Farm, Davis, California. Corn is planted as a windbreak. The tall Italian types of onions are growing in the row on the left. The other two rows are storage types. The field is the same as in figure 2.

opens, visiting insects might possibly leave foreign pollen that could function later. Although the heads may be bagged before the bracts are split, to do so usually results in a lower yield of seed.

During 1923 and 1924 a few tests were made in the field to compare the amounts of seed obtained with different methods of pollination. In 1923 the Australian Brown variety was used. The data, as given in table 1, are not very extensive, but they do show a great reduction in seed yield when bagged heads are compared with open-pollinated. The Australian Browns used in this experiment were commercial bulbs. The flower heads were covered with one-pound manila paper bags; one lot was allowed to sway freely in the wind but was not tapped by hand; the other was bagged and tied to stakes to prevent movement by the wind. Under bagged conditions, the shaking by the wind apparently tended to increase the seed yield, probably by better distribution of the pollen.

TABLE 1

Pollination Studies With the Variety, Australian Brown; 1923

Method of pollination	Number of plants	Number of seed heads	Seed harvested per head
Open-pollinated	9	24	712
Bagged, wind-shaken	9	10	157
Bagged, tied to stake	4	8	54

TABLE 2

Pollination Studies With the Variety, Ebenezer; 1924

Method of pollination	Number of plants	Number of heads	Average number of of flowers per head	Seed harvested per head	Per cent of perfect set
Open-pollinated	19	45	525	1,000	32
Emasculated, open-pollinated	7	7	498	580	19
Bagged, shaken by hand	10	21	517	205	7
Bagged, windshaken	16	28	525	99	3
Bagged, before bracts broke, wind-shaken	11	23	846	85	2

In 1924, different methods of pollination were further compared, this time with the Ebenezer variety (table 2). Because the number of flowers per head varies widely, the best method of expressing seed yield is as percentage of perfect set—which is six seeds for each flower. By far the heaviest yield of seed was obtained under open-pollinated conditions; but even then there was only a 32 per cent set. Seldom is a 50 per cent set obtained even under ideal circumstances. Emasculated heads gave a much lower set of seed than did those not emasculated, but a much higher set than did any of the bagged heads. The emasculated flowers were fertilized by pollen from other plants or from other flower heads

of the same plant. The lower set of seed from emasculated flower heads indicates that some pollination occurs between flowers of the same head. The lowest set of seed was obtained where the heads were bagged before the bracts covering the flower buds had broken. Shaking or tapping by hand gave the heaviest set of seed under bags.

TABLE 3

SEED YIELD FROM BAGGED PLANTS OF DIFFERENT VARIETIES, AT DAVIS

Year	Variety	Number of plants	Average number of seed stems	Seed yield	
				Per head	Per plant
1923	Yellow Danvers Flat	31	6.74	172	1,162
	Red Wethersfield	31	4.97	100	497
	Southport White Globe	33	3.39	146	496
	White Portugal	28	2.86	173	495
	Southport Yellow Globe	19	2.58	96	249
	Southport Red Globe	20	2.40	42	101
1924	California Early Red	28	4.07	258	1,049
	Ohio Yellow Globe	14	5.28	171	905
	Red Wethersfield	35	6.43	130	834
	Mountain Danvers	11	3.27	201	657
	Yellow Globe Danvers	80	4.74	121	573
	Australian Brown	82	4.40	117	515
	Red Bermuda	15	3.27	96	313
	Riverside Sweet Spanish	12	5.08	57	292
	Giant White Italian Tripoli	32	3.50	76	268
	Ebenezer	36	4.25	57	244
1925	Italian Red	39	4.44	207	917
	Yellow Danvers Flat	39	4.82	63	306
	Southport Yellow Globe	30	4.07	70	286
	Ebenezer (Lot 1)	29	5.27	45	238
	Ohio Yellow Globe	37	4.65	47	218
	Yellow Globe Danvers	30	4.17	47	198
	White Portugal	89	4.25	39	164
	Mountain Danvers	14	3.64	33	122
	Southport Red Globe	38	3.10	37	116
	Southport White Globe	58	3.64	32	116
	Ebenezer (Lot 2)	15	4.40	6	27
1926	Valencia	17	5.53	31	172
	Southport Red Globe	11	2.73	33	91
1928	Red Wethersfield	8	5.37	42	224
1929	Stockton Yellow Globe	37	5.89	174	1,025
1930	Australian Brown	197	7.14	219	1,568
1932	Nebuka (*Allium fistulosum*)	26	3.11*	713	2,222
	Stockton Yellow	17	6.94	159	1,106
	Red Wethersfield	19	5.00	82	412
	White Persian	73	7.55	26	195

* Only a few of the early flower heads of Nebuka were bagged.

The seed yield per plant, which varies considerably with the variety, is given in table 3 for a number of varieties. The bulbs used were from commercial stocks, selected for selfing because of certain outstanding characters. All were large. They were not planted for the purpose of comparing varieties, but obviously some yielded considerably more seed than others. Nonbolting types like Italian Red, California Early Red, Stockton Yellow, and Stockton Yellow Globe usually give a good seed yield under bags. Different strains of the same variety vary considerably. In 1925, one lot of Ebenezer averaged 238 seeds per plant; another strain, only 27. These strains also differed considerably in seed yield under conditions of open-pollination. As a rule, the white varieties yield less seed than the colored. The Nebuka (*Allium fistulosum*) types, which do not form bulbs and which are used by the Japanese as green onions, produce more seed per plant and per head than any of the commonly cultivated bulbing varieties grown in America. Also, because of more favorable climatic conditions, seed yields are much higher in some years than in others. As shown by table 3, 1924 was much more favorable for the production of seeds under bags than was 1925, when intense heat killed many of the young seeds. At Davis, on June 24, 25, and 26, maximum temperatures were 113°, 115°, and 112° F; on July 16 and 17, they were 112° and 116°. The number of seeds produced per plant decreases with inbreeding for several generations, but that matter will be discussed in another paper.

WINDBREAKS

Temporary windbreaks of corn are grown each year to protect the bagged onions from the prevailing south winds and the occasional strong north winds. In the spring, as soon as the soil is sufficiently warm, corn is planted on the outside of the field (fig. 3) and also in rows left vacant for this purpose (fig. 2).

METHOD OF INCREASING SEED

When this work was first begun, certain strains or lots of onions that were to be increased were planted in presumably isolated farming districts. Because, however, complete isolation was almost unattainable, some crossing generally occurred. The constant danger of loss, the extensive amount of traveling required, and inability to secure complete isolation necessitated the development of methods that assured control of pollination.

After several preliminary tests, the method of increasing seed under cloth cages was finally adopted, so that all the different lots can now be handled on the University Farm.

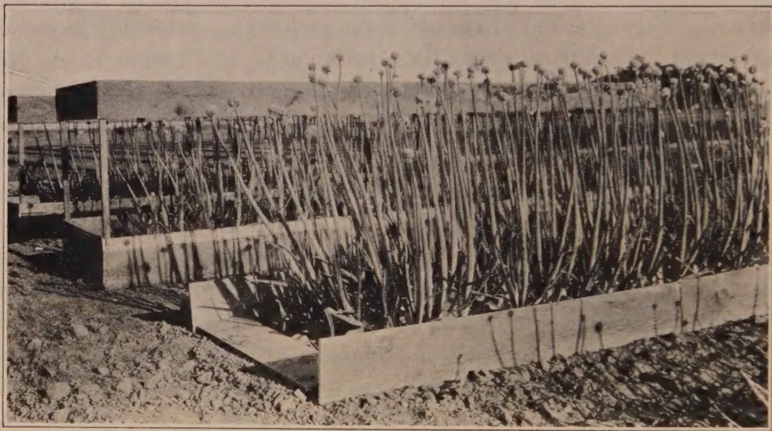

Fig. 4.—Method of planting onions in small groups. The groups are covered just before the first flowers open. This photograph shows a framework for cages being built around several different lines of California Early Red. As the seed stems of this variety are exceptionally tall, a high cage is needed.

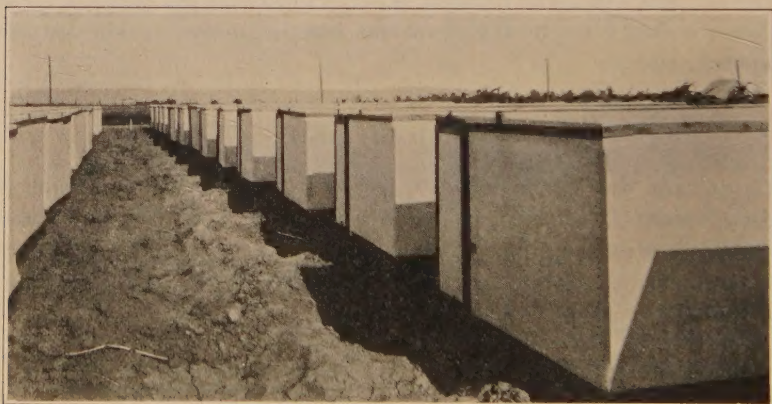

Fig. 5.—Large cheesecloth cages used for increasing seed. The cheesecloth is used for one season only. The same lumber is used year after year.

The bulbs of selections that are to be increased are planted in the field in late November. They are set 4 to 6 inches apart in two shallow parallel furrows about 2 feet apart and 15 feet long. In the spring, just before the plants begin to bloom, they are covered with cages made of a framework of boards upon which cheesecloth is tacked. Stakes are first driven into the ground at the corners and midway along the sides.

A 12-inch board (fig. 4) is then placed around the bottom and sunk in the ground about 2 inches. Around the top and lengthwise through the center, boards are nailed; around the sides is tacked a 3-foot width of cheesecloth (fig. 5). Two widths of the latter material are placed across the top, well lapped, and tacked to the sides and top so as not to pull out. A door is made in one end to permit entrance to the cage. For most varieties a cage 4 feet high is sufficient (fig. 6); but Italian Red,

Fig. 6.—Interior view of a large onion cage about three weeks after enclosing the plants. Variety, White Persian.

California Early Red, and the like, require one 6 feet high. Under Davis conditions, apparently, the best results follow when the large cages are placed at right angles to the prevailing winds; this arrangement probably permits a greater movement of air inside.

Means must be provided for pollination within the cages. Both bees and flies have been tried; but the latter, being more easily handled, have proved more satisfactory. The flies are propagated under controlled conditions in order to insure that adults will be free from foreign pollen. Slaughterhouse refuse, mainly beef lungs, is placed in open troughs. This attracts various species of adult flies, the most prevalent being

Phormia regina Meig., the sheep wool maggot, and *Lucilia sericata* Meig., the green blow-fly. They deposit their eggs in large numbers. During onion-pollination time, as a rule, the larvae hatch in 24 to 36 hours and begin to feed. Lungs are an especially good medium, being porous and providing a large feeding area. The trough should be shaded by burlap or muslin in order to protect the larvae from the hot sun. The young larvae, being gross feeders, should be well supplied with food. After feeding for 5 to 7 days, they become restless and wander about in search of a place to pupate. This restless period lasts 4 to 8 days, during which they do not feed. They may be collected at this time by shaking the pieces of lungs so the larvae will fall into the trough. Then they work their way to the end of the trough and drop into a bucket of fine-screened sand, into which they burrow before pupating. After all the larvae have pupated, the pupae are recovered from the sand by screening; then they are washed by running a fine stream of water over the screen and are dried by spreading a thin layer on a newspaper and stirring it frequently. When completely dry, the pupae are placed on a paper plate, on top of which another plate is inverted, the edges being fastened with clips. If cold storage is available, the pupae can be kept for a considerable time. At 45° F the flies emerge in about two weeks; at 37° F they can be kept for several months. If stored at various temperatures, practically mature pupae will be available at all times. A succession of broods should be maintained so that pupae can be added to the cages every three or four days. The time required to produce a generation of flies under natural conditions varies greatly with the season, being considerably longer in the spring than later when temperatures are high.

By starting to propagate the flies early in the year and then holding the pupae in cold storage, one can have a large supply in readiness for the pollinating season. When the plants begin to bloom, a small handful of pupae are placed in the cage every three or four days; thus the number of flies within the cage can be held fairly constant.

A high percentage of the developing seed within the cage is often killed during periods of excessive heat. This may not occur in locations where lower temperatures prevail during this part of the year. At best this method can be used only to increase small amounts of seed. Sufficient seed should be obtained from a cage (fig. 5) to plant ⅛ to ½ acre, and this will furnish sufficient bulbs to plant a considerable acreage for seed.

CROSSING

The method selected for controlled cross-pollination depends upon several factors. When the hybrids that result from the crossing of two plants can be easily identified, the following method is generally used. Bulbs are set side by side, about a foot apart. Usually two of each kind are planted so that if one is killed or dies, another remains; most of the plants, however, survive. If exact genetic studies are being made, only two parent plants are kept; but if improved commercial types are desired, without regard for genetic records, several plants of each strain

Fig. 7.—Muslin and cheesecloth cages used for crossing. These cages are so constructed that they can be taken apart at the close of the season and stored.

are permitted to grow. These small lots are covered with cages about 3 feet square and 6 feet high (fig. 7). Into one side of the cage is sewed a sleeve through which fly pupae can be introduced. The cages are left in place until the seed is mature. Seed from different strains or parents is harvested separately and later planted separately. In some cases the hybrids can be selected in the seedling stage; in others, the bulbs must be grown.

A few examples will illustrate the amount of crossing that occurs under the cages and the method of selecting hybrids. In 1931 there were placed under one of the small cages two bulbs of Stockton Yellow (inbred one generation) and a single bulb of Italian Red (inbred four generations). The Italian Red is bottle-shaped; the Stockton Yellow, flat. In the seedling stage, because red is dominant, it is possible to select the hybrids among the progeny of the yellow parent, but not among the

progeny of the Italian Red. Because, however, the mature bulbs are intermediate in shape between the two parents and very much larger, the hybrids in the population from each parent can be selected accurately. Part of the seed from the Stockton Yellow parent was planted, and a total population of 315 plants was grown. Of this number, 76 (about 24 per cent) were crosses with the Italian Red. Some seed of the Italian Red parent was planted, and a population of 282 plants was grown. Of this number, 79 (about 28 per cent) were crosses with Stockton Yellow.

In 1931 two excellent strains of Yellow Globe Danvers that had been inbred for two generations were placed under a small cage. Two bulbs of each strain were planted, the plants were covered, and flies were added. When mature, the seed was harvested and planted. From one line was grown a population of 200 plants, of which only 10 individuals (5 per cent) were hybrids. From the other line was produced a population of 193 plants, of which 32 (about 16 per cent) were hybrids. In this case, the hybrids could not be selected in the seedling stage: the plants had to be grown to maturity, at which time the hybrids could be picked out because of their pronounced manifestation of vigor. The relatively small amount of crossing here can be explained, at least in part, by the fact that the flowering periods of these two strains do not exactly coincide, although they do overlap considerably.

In 1932 it was desired to secure a large number of hybrid plants between the varieties Crystal White Wax and White Persian, the latter being resistant to thrips. Under a cheesecloth cage, 6 feet square, were planted 11 bulbs of Crystal White Wax and 3 of White Persian. Flies were used for pollination. From the 3 White Persian plants was harvested 75 grams of seed; from the 11 Crystal White Wax, 200 grams. The White Persian variety has foliage of a very light-green color, which is recessive to the dark-green of Crystal White Wax. If seed of the White Persian is planted the hybrids can be selected in the seedling stage by the dark foliage color. When a portion of the seed from the White Persian was planted, the total population of seedlings was 264; of this number, 73 (about 27.5 per cent) were crosses.

In cases where the hybrid is not distinct, one parent will have to be emasculated. The umbels of the plants to be crossed are bagged as soon as the first flower opens. At first only a few flowers on an umbel open daily. The number increases until full bloom, when fifty or more may open in a single day. The flowers are removed each morning and afternoon, until about 50 open flowers can be secured in one or two days. If the weather is especially hot, they must be removed oftener, because the

anthers may shed their pollen very soon after the flower opens. Emasculation is conducted several times daily until about 50 emasculated flowers have been secured. Then all the buds are removed, a flower head of the pollen parent is tied with the emasculated head, and both are enclosed under the same bag (fig. 8). The bags are tapped several times each day to facilitate pollination, or, better still, flies are enclosed within the bag to do the pollinating. To secure pollen-free flies for crossing, pupae are placed in a paper plate, which is wrapped with cheesecloth

Fig. 8.—Method of tying umbels together for crossing. The one on the right has been emasculated; the other supplies the pollen. The umbels are then enclosed in a paper bag. Flies are enclosed to do the pollinating. Sometimes pupae are also included.

and set in a warm place. When the flies have emerged, they are taken to a low-temperature chamber (about 37° F). After chilling, they can be easily caught and placed in small glass vials, the corks being notched to permit ventilation. The adult flies needed for one bag are placed in a vial and are liberated in the bag at the time the two heads are tied together. The heads are bagged separately when pollination has been completed—usually 4 or 5 days after they have been tied together.

When plants to be crossed are not growing side by side, an umbel of the pollen parent can be removed and tied securely to the umbel that is to be pollinated; then the two are enclosed under a bag as in the method described above.

When flies or other insects are not used, the same method of emasculation is used; but pollination must be done by hand, at a time when the styles are fully extended. The pollen of the male parent can be collected on a watch glass, and the pollen-covered surface touched against the stigma of the female. As a rule, each flower must be pollinated several times in order to get even a fair set of seed.

Some investigators report that most of their crossing is done in the greenhouse. In the work reported here pollination was generally done in the field; but when the length of pollinating season had to be increased, plants have been brought to bloom in the greenhouse considerably earlier than out of doors. Conditions there are much more favorable for work; no wind or dew, and fewer insects, will interfere. Under Davis conditions, apparently, the best method for greenhouse pollination is to set the mother bulbs, late in November, in large pots which are sunk in the ground out of doors. Considerable root growth and some foliage development are made during the winter. About the time the seed stems are formed—usually late in February—the plants are removed from the pots and placed in a greenhouse bench. The higher temperature of the greenhouse usually brings the plants into bloom at least a month sooner than out of doors.

HARVESTING AND CURING SEED

The bags are allowed to remain on the heads until the seed is ripe. Then the stems are cut below the bags, and all the heads of a plant are tied together and placed in well-aerated crates in the open until thoroughly dry. Next, the heads are placed in cloth bags, and the seed is

Fig. 9.—Rubber washboard used to thresh small lots of onion seed. After threshing, the seed and chaff are brushed into a beaker of water. The heavy seed sinks to the bottom, while the light seed and chaff are floated off.

rolled out. Probably a better method is to remove the seed by use of a rubber washboard (fig. 9). Seed capsules matured under a bag contain considerable nectar, which is rather hygroscopic, taking up moisture rapidly during humid weather and making threshing difficult. Threshing is most efficient during hot, dry weather. When well threshed, the seed and chaff are emptied into a container with water, and the light seed and chaff floated off. When single plants are being threshed separately, a 1,000-cc beaker is generally sufficiently large for washing. After three or four changes of water, the seed is usually clean and is spread thinly on paper to dry; it is then placed in small envelopes. A common mistake is to bag or package seed not sufficiently dry, causing it to mold.

GROWING SEEDLINGS

For a number of years the onion seed of all the selfed lines of storage types was sown directly in the field. Although this method avoided the setback from transplanting, and cost less, it failed to provide a uniform stand of plants from which accurate comparisons could be made; it involved, furthermore, a great waste of seed. After several trials, accordingly, it was replaced by the transplanting method, which has since been used for all the breeding work.

There are two general seasons for seeding onions in this district. The nonbolting or Italian types such as California Early Red, Italian Red, Stockton Yellow Globe, and Giant White Italian Tripoli are sown in late August or early September. At Davis these varieties are always sown in coldframes and are usually transplanted to the field in November or December. About a month before sowing, the soil is sterilized with a formalin solution to kill the damping-off fungi and the pink-root organism, *Phoma terrestris* Hansen. The solution used contains one pint of commercial formalin to 15 gallons of water. One gallon of solution is applied to each square foot of soil. The bed is covered with burlap, wet down, and left for several days (fig. 10). When the soil is sufficiently dry it is worked into fine condition; then the seed is sown in shallow furrows, about 10 or 12 to the inch, and about 5 inches apart. Finally, the beds are covered with cheesecloth, which is left on both day and night until late October (fig. 11). Covering, in conjunction with the previous formalin treatment of the soil, prevents damage from the seed-corn maggot.

The storage varieties such as Australian Brown and Yellow Globe Danvers are usually seeded in coldframes in late November or December and transplanted to the field in February or March. Most of these varieties produce a high percentage of bolters if planted much earlier.

The soil in the coldframes is sterilized, and seeding is done as described above; but since the seed-corn maggot does no damage so late in the season, the beds are covered with a cloth only on very cold nights.

Fig. 10.—The seed beds are treated with a solution of formalin to kill the various fungus diseases in the soil. After the treatment, burlap is spread over the bed and is wet down to hold the fumes in the soil.

Fig. 11.—Growing seedlings under a cheesecloth cover to prevent attacks by the seed-corn maggot.

TRANSPLANTING

When sufficiently large, the seedlings are transplanted to the field (fig. 12). The large-growing Spanish and Italian types are set 4 inches apart in the row. On sediment soil where surface irrigation is practiced, the rows are made 18 inches apart; but on peat soil, which is subirrigated and where furrows are not necessary, the rows are 15 inches apart. The varieties that produce small bulbs are planted 3 inches apart in the row.

In the Sacramento Valley it is important to have large seedlings for transplanting and to get them into the ground early in the spring. In late February or early March, they are transplanted and kept alive without difficulty; but later, when the north winds begin and the days become longer and hotter, transplanting becomes increasingly difficult.

OUTLINE OF BREEDING PROGRAM

The onion-breeding program that most concerns the seedsmen is that of purifying stocks. With most varieties this consists, mainly, in eliminating colors, shapes, and other characters not true to the variety. With many other crops, the method is to self a large number of desirable plants, grow the progeny, discard the off types, and continue this process

Fig. 12.—Inbred lines and strains of onions are tested in single-row plots, usually replicated three times.

until the progeny are uniform for the desired characters. When continuous inbreeding is practiced with the onion, however, a gradual loss of vigor for a number of generations almost always results. This is the main disadvantage in attempting to purify onions by continuous inbreeding. Some inbreeding, however, is necessary if the most rapid progress is to be made. Lost vigor can be regained by crossing inbred lines.

The following plan, the result of our experiments to date, is suggested as the most suitable for the improvement and purification of onion varieties. Investigations now under way may later cause us to modify these recommendations somewhat.

First year: Select a large number of commercial bulbs that approach the ideal for the variety. The larger the number, the greater the chance of securing desirable lines. Plant for selfing.

Second year: Self-pollinate.

Third year: Grow progenies of each plant separately. Discard all lines that have a high percentage of off-type bulbs. Retain 25 or 30 of the best lines, and plant for selfing. These bulbs will probably be somewhat small, but size will be regained by crossing later on.

Fourth year: Self-pollinate.

Fifth year: Grow progenies of each plant separately. Discard all lines that are still segregating for important commercial characters. Retain at least 10 lines; from these select the best bulbs. It is necessary to retain a number of lines that have been derived from different bulbs at the first selection, because different lines must be crossed to regain the original vigor.

Sixth year: Group all selections and plant in the field so that the maximum amount of crossing will occur. Mass the seed.

Seventh year: Sow the seed. When the crop is mature, select large bulbs possessing the desirable characteristics for the variety; these result from desirable crosses.

In after years, stocks are maintained by selecting desirable bulbs and massing.

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